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(54) **REFRIGERANT RECOVERY AND RECYCLING SYSTEM WITH SERVICEABLE DEBRIS FILTER**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 249 days.

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**Related U.S. Application Data**

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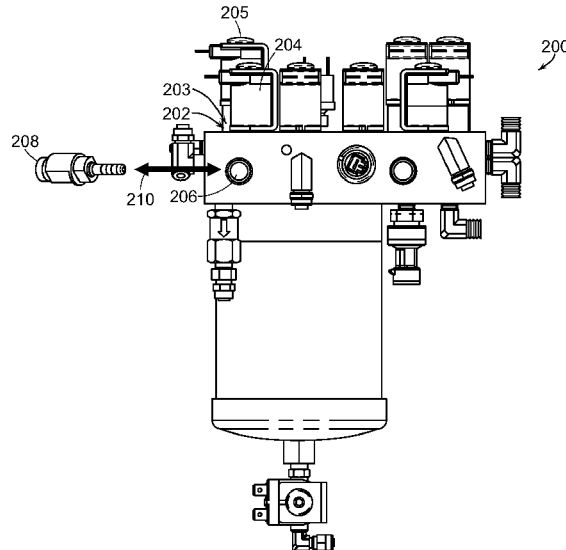
(51) **Int. Cl.**  
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**F25B 43/00** (2006.01)  
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**B60H 1/00** (2006.01)  
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(57) **ABSTRACT**

An inlet debris filter disposed within a manifold assembly and operable to filter refrigerant that flows through the manifold assembly. In some embodiments, the manifold assembly may be disposed within an air conditioning servicing system. In some embodiments, the inlet debris filter may be removable and serviceable.

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**7 Claims, 5 Drawing Sheets**



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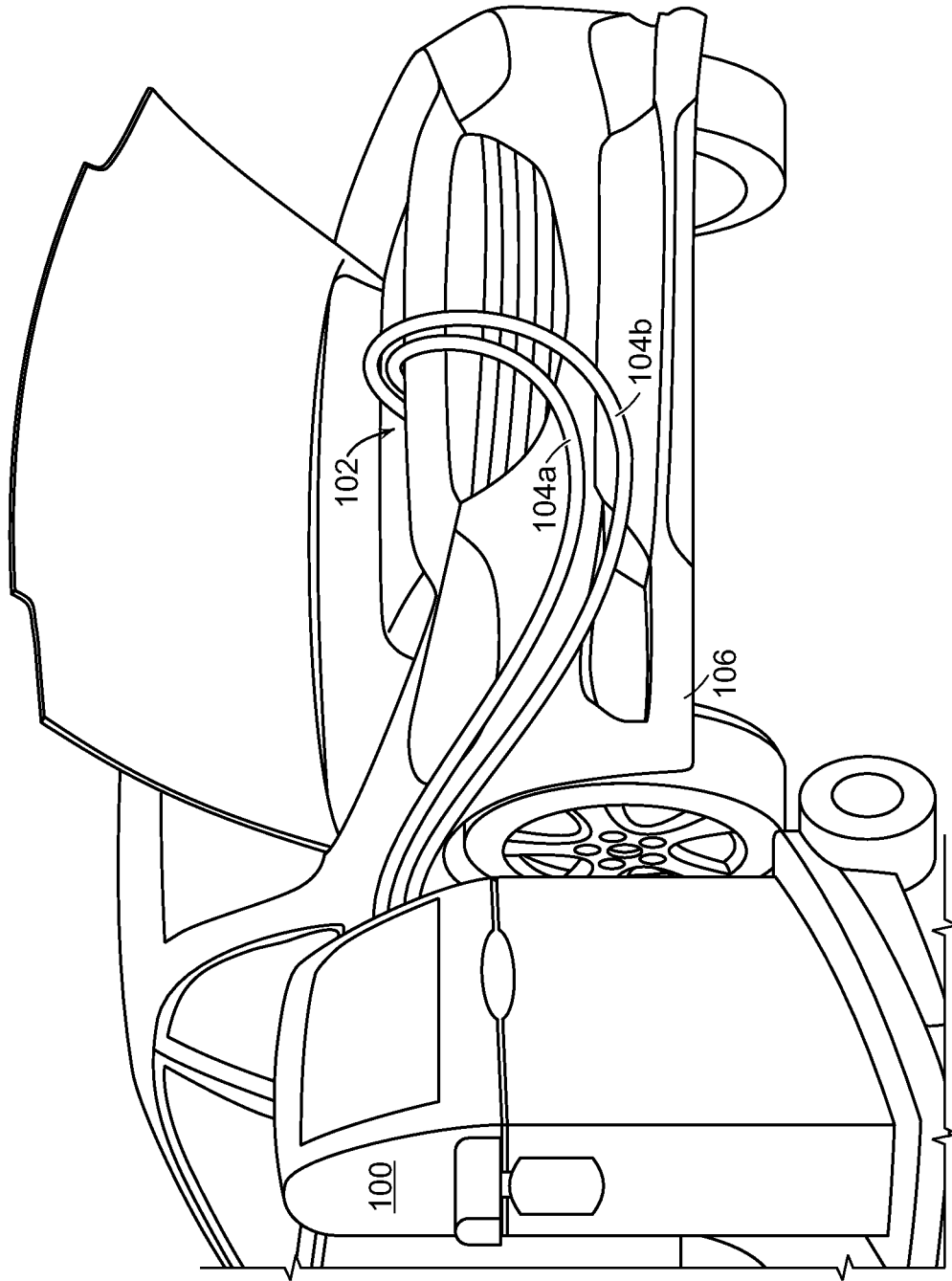


FIG. 1

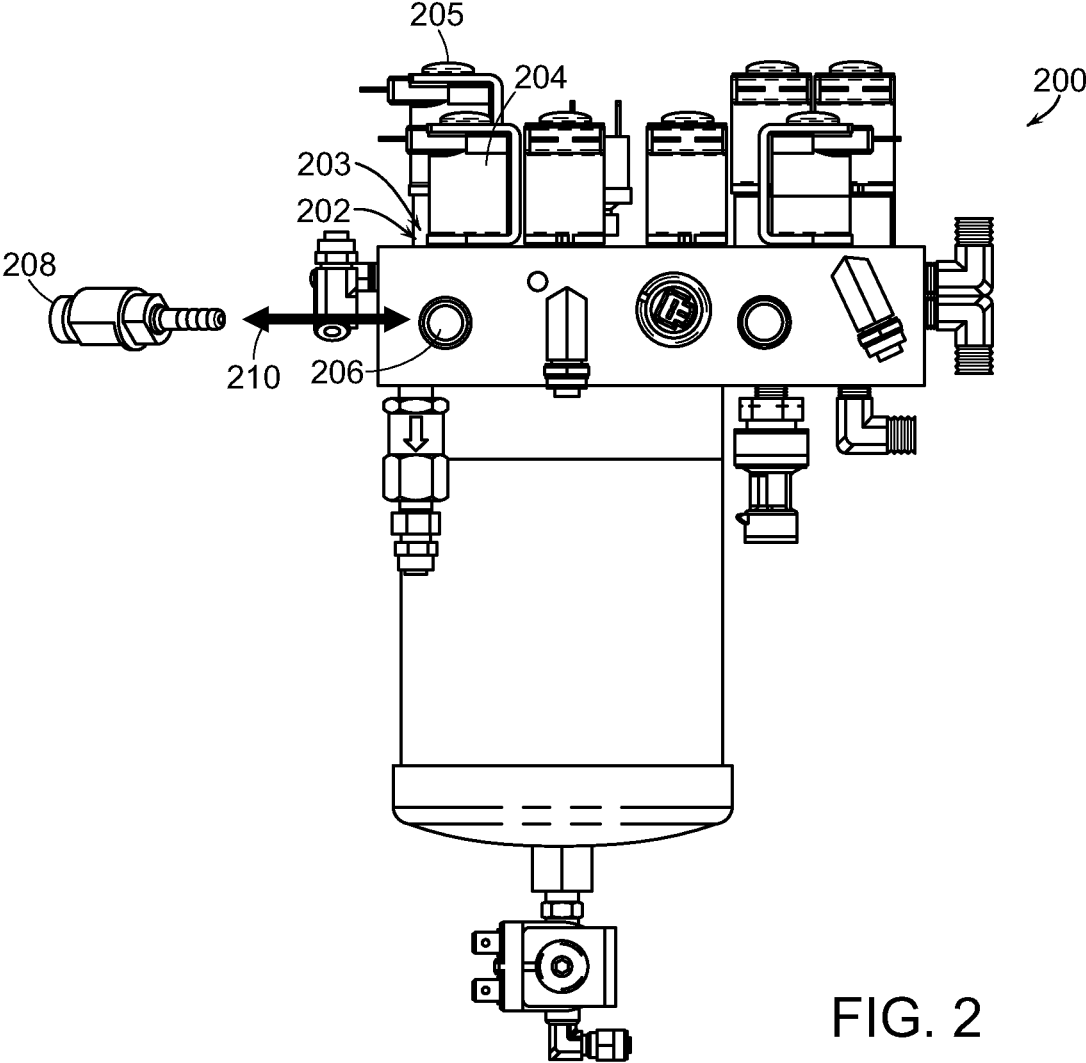


FIG. 2

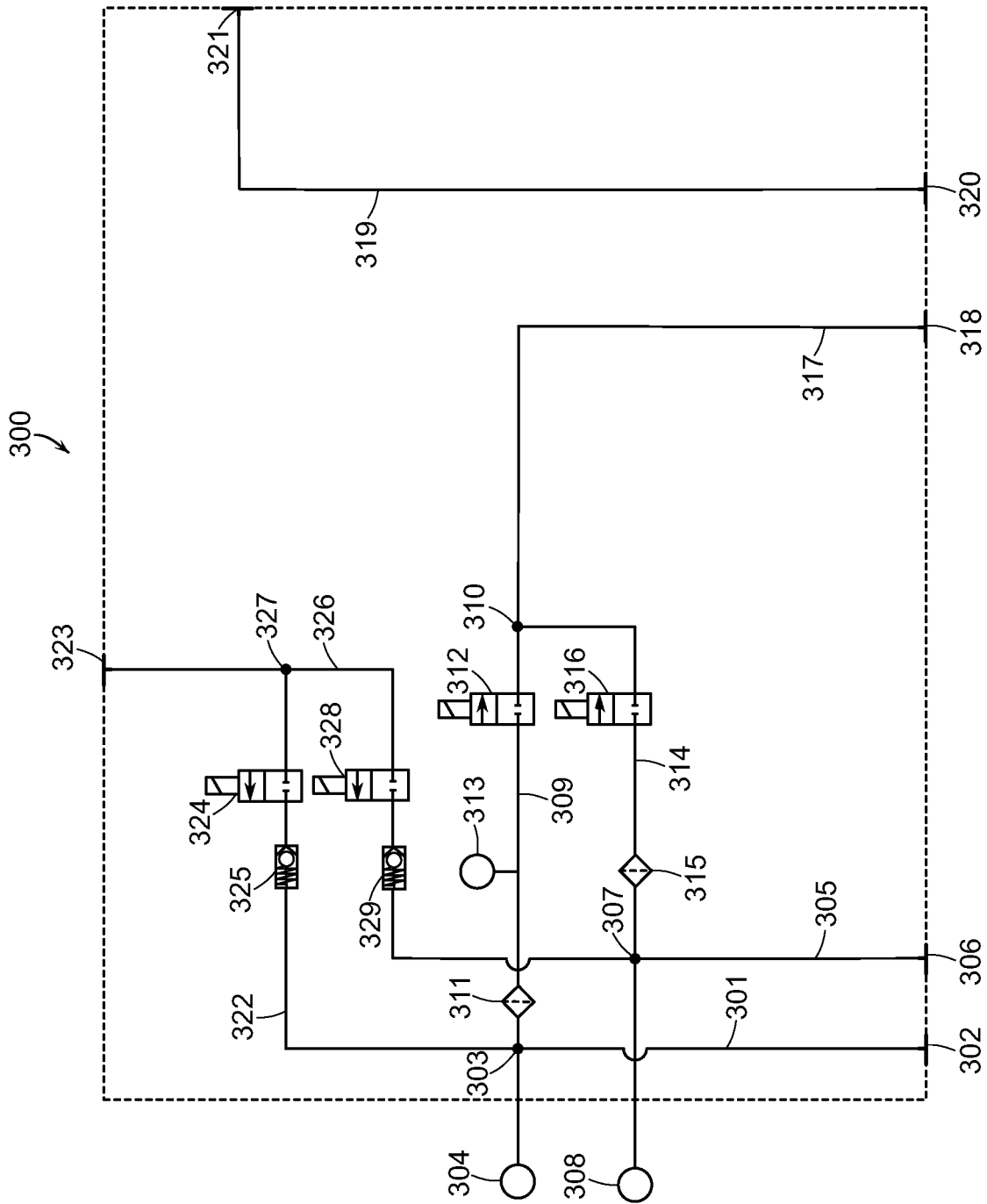


FIG. 3

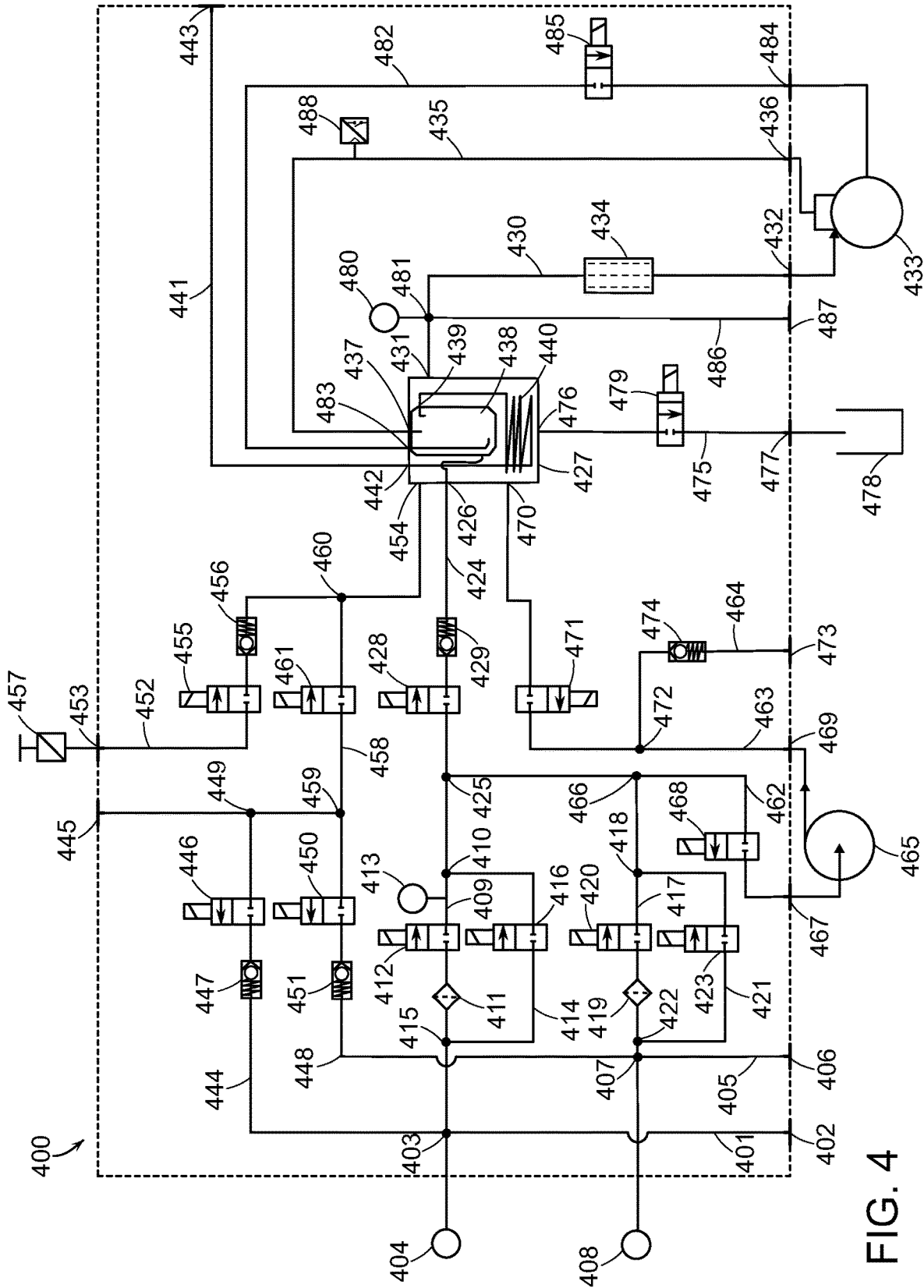


FIG. 4

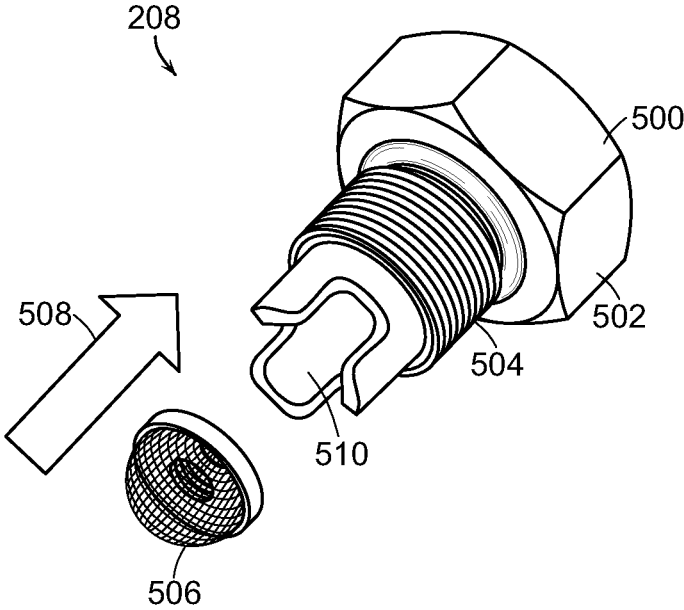


FIG. 5

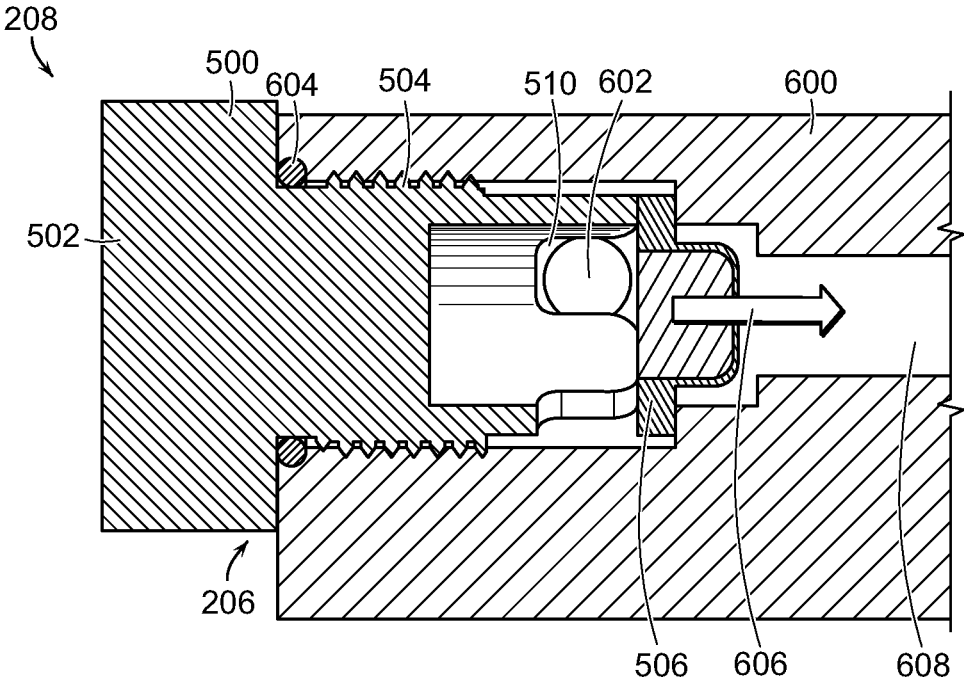


FIG. 6

## REFRIGERANT RECOVERY AND RECYCLING SYSTEM WITH SERVICEABLE DEBRIS FILTER

### TECHNICAL FIELD

This disclosure is directed to the operation and servicing of refrigerant recovery, recharging, and recycling machines used to service cooling systems and air conditioners. It is additionally related to embodiments herein directed to refrigerant recovery, recharging, and recycling machines for use with air conditioners of vehicles.

### BACKGROUND

Air conditioning service (ACS) systems are used to perform maintenance of cooling systems and air conditioners (AC). An ACS system can be used to recover refrigerant from an AC for proper reconditioning of the refrigerant according to local laws, to charge the AC with an appropriate quantity of refrigerant, to recharge the AC to appropriate quantities to optimize operation of the AC, or to recycle the refrigerant of an AC in order to purify the refrigerant of non-condensable impurities, or prepare the refrigerant for an additional recovery or recharge operation.

It is expected that impurities will be introduced to the refrigerant in the normal course of operation of an AC, including non-condensable gases and solid particulates or debris. Many ACS systems comprise a filter/drier in the circuit to remove moisture and some amount of contaminants during the recovery process. These filter/driers may be successful at protecting critical elements of the ACS system, such as the compressor, but the filter/driers are placed within the ACS system flow path such that other components upstream of the filter/driers of the ACS system remain exposed to these contaminants.

Previous ACS systems may have used a separate contamination filter outside of the service machine and in series with the service hoses that connect the ACS system to the AC being serviced. An issue with this solution, is that the refrigerant is flowing both into the ACS system during the recovery process through the contamination filter, but then also out of the ACS system during the charge process backwards through the contamination filter, and any debris caught in such hose filters during the recovery process may be flushed back into the AC system during the charge process. This protects the inner workings of the ACS system, but debris remains inside the inner workings of the AC instead, where it can cause damage or malfunction in the AC. Therefore, it is desirable to implement a debris filter of an ACS system that is operable to prevent debris from harming the ACS system without permitting the return of debris to the refrigerant path of the AC during a service operation.

### SUMMARY

In one aspect of the present disclosure is directed to an air conditioner service system that includes a serviceable inlet debris filter that protects both the air conditioner service system and the air conditioner from debris in the refrigerant during a service operation without permitting the debris to be flushed into the air conditioner service system or back into the air conditioner.

Another aspect of the disclosure herein is directed to a manifold assembly of an air conditioner service system having a removable filter cartridge housing an inlet debris

filter, the removable filter cartridge configured to filter debris to protect the other system components in the manifold flow path. In some embodiments, the debris filter is disposed within the manifold assembly such that refrigerant will only flow through the filter in one direction, thus any debris that is captured will stay in the filter until the filter is removed.

A further aspect of the teachings herein is directed to an embodiment of an air conditioner service system having a reusable inlet debris filter, wherein the air conditioner service system is operable to monitor the status of the inlet debris filter and to indicate to a user when the inlet debris filter must be cleaned. In some embodiments, the reusable inlet debris filter may be bypassed when the status indicates that cleaning is required.

A further aspect of the teachings herein is directed to a removable filter cartridge disposed within a manifold assembly of an air conditioner service system. The removable filter cartridge is operable to provide an inlet debris filter to the manifold assembly configured to protect the components of the air conditioner service system disposed within the manifold assembly.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic illustration of an air conditioner service system connected to an air conditioner of a vehicle during a service operation.

FIG. 2 is a side view of a manifold assembly of an air conditioner service system incorporating a debris filter.

FIG. 3 is a flow diagram of one embodiment of a manifold assembly of an air conditioner service system disclosed herein.

FIG. 4 is a flow diagram of another embodiment of an air conditioner service system disclosed herein.

FIG. 5 is an isometric view of a removable filter cartridge, wherein the removable filter cartridge is configured to provide an inlet debris filter in the flow path of a manifold assembly.

FIG. 6 is a diagrammatic cross-sectional view of a removable filter cartridge when installed in a manifold assembly.

### DETAILED DESCRIPTION

The illustrated embodiments are disclosed with reference to the drawings. However, it is to be understood that the disclosed embodiments are intended to be merely examples that may be embodied in various and alternative forms. The figures are not necessarily to scale and some features may be exaggerated or minimized to show details of particular components. The specific structural and functional details disclosed are not to be interpreted as limiting, but as a representative basis for teaching one skilled in the art how to practice the disclosed concepts.

It is recognized that some terms of the art may be used interchangeably. The language herein is intended to provide illustration and not limitation to the disclosure, unless otherwise noted within the disclosure. One of ordinary skill in the art will recognize that the teachings herein may be described using alternative terminology or depiction.

FIG. 1 depicts an isometric view of an air conditioning service (ACS) system **100** during a service operation of an air conditioner (AC) **102**. ACS system **100** is operably connected to AC **102** using a number of hoses **104**. In the depicted embodiment, these hoses comprise a low-side hose **104a** and a high-side hose **104b**, though other embodiments may comprise a different number of hoses. Low-side hose **104a** may also be referred to as a "liquid" connection,

so-named because ACS system **100** is configured such that liquid refrigerant is expected to flow through low-side hose **104a** from a corresponding port of ACS system **100** to a corresponding port of AC **102**. High-side hose **104b** may also be referred to as a “gaseous” or “vapor” connection, so-named because ACS system **100** is configured such that gaseous refrigerant is expected to flow through high-side hose **104b** from a corresponding port of ACS system **100** to a corresponding port of AC **102**. FIG. 1 depicts ACS **102** as being disposed within a vehicle **106**, but other embodiments of the teachings herein may not comprise vehicle **106**.

FIG. 2 is a side-view of a manifold assembly **200** providing fluid communication for components of ACS system **100** according an embodiment of the teachings herein. It is recognized that fluid communication can be achieved by channels within manifold assembly **200**, the channels being defined by the manifold assembly and configurable using additional elements disposed within the channels. It is recognized that one of ordinary skill in the art would consider the term “channel” to be synonymous with other terms of the art, such as “passage,” “flow path,” “circuit,” “conduit,” or the like. For purposes of illustration and not limitation, any of these terms may be used herein exclusively with respect to a one embodiment, but other synonymous terms may be used instead for other embodiments for purpose of clarity. Manifold assembly **200** comprises a number of ports along its periphery to enable fluid communication of the channels therein and connect, through external tubing or structures, with other components of the system not disposed within manifold assembly **200**. In the depicted embodiment, these ports comprise at least a low-side inlet port **202** and high-side inlet port **203**. In the depicted embodiment, low-side inlet port **202** is configured to have flow from low-side hose **104a** (see FIG. 1) controlled by a low-side inlet solenoid **204**. In the depicted embodiment, high-side inlet port **203** is configured to have flow from high-side hose **104b** (see FIG. 1) controlled by a high-side inlet solenoid **205**.

Manifold assembly **200** further comprises a cartridge port **206** configured to receive a filter cartridge **208**. Filter cartridge **208** may be removed from or inserted into cartridge port **206** along a direction vector **210**. Filter cartridge **208** comprises a debris filter, and when filter cartridge **208** is inserted into cartridge port **206**, the debris filter is disposed along a flow path between the inlet ports **202-203** and additional components disposed within the flow paths of manifold assembly **200**. Advantageously, manifold assembly **200** may be configured such that the debris filter is disposed between inlet ports **202-203** and their respect inlet solenoids **204-205**, which protects low-side inlet solenoid **204** and high-side inlet solenoid **205** from corrosion or mechanical wear caused by debris in the refrigerant. In some embodiments, manifold assembly **200** may comprise a plurality of cartridge ports **206** to receive a corresponding plurality of filter cartridges **208**. For example, if manifold assembly **200** comprises a low-side inlet port **202** and a high-side inlet port **203**, there may be two distinct cartridge ports **206**, each configured to accept a corresponding filter cartridge **208**. In other embodiments, manifold assembly **200** may be configured to have a single cartridge port **206** to accept a single filter cartridge **208** in order provide a debris filter for an arbitrary number of inlet ports.

FIG. 3 depicts a flow diagram of a manifold assembly **300** disposed within an ACS system according to one embodiment of the teachings herein. The manifold assembly channels provide operable fluid communication between the channels of manifold assembly **300** and other components of

the ACS system. The operable fluid communication of the channels disposed therein may be configured using components disposed within the channels. For the purposes of illustration and not limitation, each “channel” as described herein will refer to a sub-portion of the total flow path of manifold assembly **300** comprising a section of flow path disposed between an arbitrary starting point called a “head terminus”, and an arbitrary ending point called a “tail terminus.” A terminus may comprise a particular component disposed within the channel, a particular element or aspect of a particular component within the channel, a port providing fluid communication with the channel, or an arbitrary point along the channel. Termini are not necessarily physical features of a channel, and are referred to herein for the purpose of clarity in describing the embodiment. “Head” termini are referred to as such because they are useful starting points to provide clear description of the embodiment, and the term should not be construed to provide any further meaning. “Tail” termini are referred to as such because they are useful ending points to provide clear description of the embodiment, and the term should not be construed to provide any further meaning. It is recognized that one of ordinary skill in the art would consider the term “terminus” to be synonymous with other terms of the art, such as “locus,” “endpoint,” “extremum,” “focus,” or the like. For purposes of illustration and not limitation, any of these terms may be used herein exclusively with respect to a one embodiment, but other synonymous terms may be used instead for other embodiments for purpose of clarity. Within manifold assembly **300** one or more channels may intersect, and a point of intersection may be referred to as a “node.” It is recognized that one of ordinary skill in the art would consider the term “node” to be synonymous with other terms of the art, such as “junction,” “intersection,” “vertex,” or the like. Nodes are not necessarily physical features of one or more channels, and are referred to herein as such for the purpose of clarity in describing the embodiment. Nodes may or may not serve as a head terminus or tail terminus of one or more channels.

In the depicted embodiment, some channels and components thereof may be described using ordinal signifiers (“a first channel”, “a second channel”, etc.). These ordinal signifiers are only referred to as such for the purpose of clarity in describing the embodiment and should not be construed to provide any further meaning. One of ordinary skill in the art will recognize that some alternative embodiments may comprise similar but not identical channels. For the purposes of clarity with respect to these alternative embodiments, the channels will be referred to using the same ordinal signifiers, even if use of those labels is not technically correct from a semantic view (e.g., an alternative embodiment may comprise a “first channel” and a “third channel” but not a “second channel”). With respect to the disclosure herein, ordinal signifiers may be considered as an arbitrary labeling mechanism.

With further respect to FIG. 3, manifold assembly **300** defines a first channel **301** with a low-side inlet port **302** serving as a head terminus and a node **303** serving as a tail terminus. Low-side inlet port **302** provides fluid communication of refrigerant between manifold assembly **300** and other components of the surrounding ACS system. In the depicted embodiment, low-side inlet port **302** is configured to be in operable fluid communication of refrigerant with a low-side refrigerant port of the AC during service operations. First channel **301** is characterized by fluid communication with a low-side inlet pressure transducer **304**, which in the depicted embodiment is disposed outside of the

periphery of manifold assembly **300**. Low-side inlet pressure transducer **304** measures the pressure within first channel **301** and is operable to provide those measurements to a user or another component of the ACS system. In some embodiments, low-side inlet pressure transducer **304** may be embodied instead as an analog pressure gauge. In some embodiments, pressure transducer **304** may be disposed within the periphery of manifold assembly **300**.

Manifold assembly **300** also comprises a second channel **305** with a high-side inlet port **306** serving as a second head terminus and a node **307** serving as a second tail terminus. High-side inlet port **306** provides fluid communication of refrigerant between manifold assembly **300** and other components of the surrounding ACS system. In the depicted embodiment, high-side inlet port **306** is configured to be in operable fluid communication of refrigerant with a high-side refrigerant port of the AC during service operations. Second channel **305** is characterized by fluid communication with a high-side inlet pressure transducer **308**, which in the depicted embodiment is disposed outside of the periphery of manifold assembly **300**. High-side inlet pressure transducer **308** measures the pressure within second channel **305** and is operable to provide those measurements to a user or another component of the ACS system. In some embodiments, high-side inlet pressure transducer **308** may be embodied instead as an analog pressure gauge. In some embodiments, high-side inlet pressure transducer **308** may be disposed within the periphery of manifold assembly **300**.

Node **303** also functions as a third head terminus for a third channel **309**, which is further defined with a node **310** providing a third tail terminus. Disposed within third channel **309** is a low-side inlet debris filter **311** and a low-side inlet solenoid **312**. Low-side inlet solenoid **312** is configured to prevent flow of refrigerant between the third head terminus **303** and the third tail terminus **310** when closed. A solenoid, as used herein, is a normally closed valve, via a spring or fluid back-pressure, which may be opened by providing electricity to an electrical solenoid which opens the valve by creating a magnetic field and pulling a metal plunger out of the flow path, although other automated, electrical, magnetic, or manual valves may be used. In the depicted embodiment, low-side inlet debris filter **311** is disposed closer to the third head terminus at node **303** than low-side inlet solenoid **312**, but other embodiments may have other arrangements of third channel **309**. Advantageously, disposing low-side inlet debris filter **311** nearer to third head terminal **303** protects low-side inlet solenoid **312** from corrosion and malfunction caused by debris in the refrigerant flowing from third head terminus **303**.

In some embodiments, low-side inlet debris filter **311** may be configured such that it may be removed from the channel for the purpose of servicing or replacement. In some embodiments, low-side inlet debris filter **311** may be disposed within a filter cartridge, such as depicted in FIG. 2. In some embodiments, low-side inlet debris filter **311** may be reusable, and may be serviced or cleaned as needed when removed before being placed back into third channel **309**.

Also disposed within third channel **309** in this embodiment is a filter pressure transducer **313**. Filter pressure transducer **313** measures the pressure within third channel **309** and is operable to provide those measurements to a user or another component of the ACS system. The difference between the measurements of filter pressure transducer **313** and low-side inlet pressure transducer **304** may be used to monitor the status of inlet debris filter **311**. If the pressure difference is substantially large, low-side inlet debris filter **311** may be clogged and require servicing. In some embodi-

ments, the ACS system may calculate the difference in pressure measurements automatically and provide an indication that the low-side inlet debris filter **311** requires servicing if the difference is above a predetermined threshold value. In the depicted embodiment, the fluid communication point of filter pressure transducer **313** with third channel **309** is disposed between low-side inlet debris filter **311** and low-side inlet solenoid **312**, other embodiments may comprise other configurations. In practice, filter pressure transducer **313** will be operable when in fluid communication with any point of third channel **309** disposed between low-side inlet debris filter **311** and third tail terminus **310** when low-side inlet solenoid **312** is open. Advantageously, in embodiments where filter pressure transducer **313** is disposed nearer to third head terminus **303** than low-side inlet solenoid **312**, the measurements obtained by filter pressure transducer **313** will be useful even if low-side inlet solenoid **312** is closed. In some embodiments, filter pressure transducer **309** may be embodied instead as an analog pressure gauge. In some embodiments, filter pressure transducer **313** may be disposed outside the periphery of manifold assembly **300**, but still in fluid communication with the third channel.

Manifold assembly **300** further comprises a fourth channel **314**, disposed between a fourth head terminus at node **307** and a fourth tail terminus at node **310**. Disposed within fourth channel **314** is a high-side inlet debris filter **315** and a high-side inlet solenoid **316**. High-side inlet solenoid **315** is configured to prevent flow of refrigerant between the fourth head terminus **307** and the fourth tail terminus **310** when closed. In the depicted embodiment, high-side inlet debris filter **315** is disposed closer to the fourth head terminus at node **307** than high-side inlet solenoid **316**, but other embodiments may have other arrangements of fourth channel **314**. Advantageously, disposing high-side inlet debris filter **315** nearer to fourth head terminal **307** protects high-side inlet solenoid **316** from corrosion and malfunction caused by debris in the refrigerant flowing from fourth head terminus **307**.

In some embodiments, high-side inlet debris filter **315** may be configured such that it may be removed from the channel for the purpose of servicing or replacement. In some embodiments, high-side inlet debris filter **315** may be disposed within a filter cartridge, such as depicted in FIG. 2. In some embodiments, high-side inlet debris filter **315** may be reusable, and may be serviced or cleaned as needed when removed before being placed back into fourth channel **314**.

It is noted that in the depicted embodiment, node **310** serves as the tail terminus for both third channel **309** and fourth channel **314**. Thus, third channel **309** and fourth channel **314** are in fluid communication. In some embodiments, this permits filter pressure transducer **313** to be used to monitor the status of high-side inlet debris filter **315**. In embodiments or configurations in which high-side inlet debris filter **315** is in operable fluid communication with filter pressure transducer **313** (e.g., embodiments wherein filter pressure transducer **313** is in direct fluid communication with node **310**), the measurements provided by filter pressure transducer **313** can provide an indication that high-side inlet debris filter **315** may require servicing if the pressure difference between the measurements of filter pressure transducer **313** and high-side inlet transducer **308** is above a threshold value. In practice, filter pressure transducer **313** will be operable when in fluid communication with any point of fourth channel **314** disposed between high-side inlet debris filter **315** and fourth tail terminus **310** when low-side inlet solenoid **312** is open and high-side inlet

solenoid **316** is open, though in other non-depicted embodiments the status of low-side inlet solenoid **312** may not affect the usability of filter pressure transducer **313** in this manner. In other contemplated embodiments, an additional transducer may be in direct fluid communication with the fourth channel **314** between high-side inlet debris filter **315** and fourth tail terminus **310**. In such an embodiment, the utility of the additional transducer to monitor the status of high-side debris inlet filter **315** may or may not depend upon the status of high-side inlet solenoid **316**, depending upon the particular point within fourth channel **314** with which the additional transducer is in fluid communication. If the fluid communication point of an additional transducer is disposed between high-side inlet debris filter **315** and high-side inlet solenoid **316**, the operable status of high-side inlet solenoid **316** has no particular effect on the utility of pressure differences in monitoring the status of high-side inlet debris filter **315**.

Node **310** additionally serves as the fifth head terminus of a fifth channel **317**, which also is defined by a fifth tail terminus at a compressor inlet port **318** of manifold assembly **300**. Compressor inlet port **318** is configured to be in fluid communication with the inlet of a compressor (not shown) of the ACS system. In the ACS system, the compressor is operable to increase the pressure of refrigerant to ensure that it is placed into a gaseous form. Refrigerant in gaseous form is desirable for certain functions of the ACS system, such as a recovery operation intended to empty the refrigerant from the AC and store the refrigerant into a storage tank. In some embodiments, the compressor may not be active during certain service operations

Refrigerant returns from an outlet of the compressor to a sixth channel **319** of manifold assembly **300** via a compressor return port **320**, which also serves as a sixth head terminus for sixth channel **319**. Sixth channel **319** provides a flow path through manifold assembly **300** between the compressor return port **320** and a tank inlet port **321** also serving as a sixth tail terminus for sixth channel **319**. Tank inlet port **321** is configured to provide fluid communication between manifold assembly **300** and an inlet valve of a refrigerant storage tank (not shown). In the depicted embodiment, sixth channel **319** of manifold assembly **300** provides fluid communication between the return of the compressor and an inlet of the storage tank. Other embodiments may have other configurations for providing a flow path between the compressor outlet and the storage tank inlet, including flow paths disposed outside of manifold assembly **300**, without deviating from the scope of the disclosure herein.

Manifold assembly **300** also defines a seventh channel **322**, starting with a seventh head terminus defined by a tank charge port **323** and ending with a seventh tail terminus at node **303**. It is noted that node **303** also serves as the first tail terminus of first channel **301**, and thus seventh channel **322** provides a flow path through the manifold assembly **300** from tank charge port **323** to low-side inlet port **302**. Tank charge port **323** is configured to be in fluid communication with a refrigerant source disposed externally to the manifold assembly **300**, such as the refrigerant storage tank. Disposed within the seventh channel **322** is a low-side charge solenoid **324**, configured to operably control flow of refrigerant between seventh head terminus **323** and seventh tail terminus **303**. A low-side charge check valve **325** is further disposed within seventh channel **322**, and is configured to only permit flow of refrigerant from seventh head terminus **323** toward seventh tail terminus **303**. In the depicted embodiment, low-side charge solenoid **324** is disposed within seventh channel **322** nearer to seventh head terminus

**323** than low-side charge check valve **325**, but other arrangements may be embodied without deviating from the disclosure herein.

Manifold assembly **300** also defines an eighth channel **326**. Eighth channel **326** is also defined with an eighth head terminus at tank charge port **323**, with the eighth channel **326** branching from the seventh channel **322** at node **327**. The eighth channel **326** is further defined by an eighth tail terminus at node **307**. Node **307** is disposed within eighth channel **326** between eighth head terminus **323** and the other elements of the eighth channel **326**, including a high-side charge solenoid **328** and a high-side charge check valve **329**. High-side charge solenoid **328** is configured to operably control flow of refrigerant between the eighth head terminus **323** and the eighth tail terminus **307**. High-side charge check valve **329** is configured to only permit flow of refrigerant from eighth head terminus **323** to eighth tail terminus **307**.

In the depicted embodiment, node **327** is disposed away from tank charge port **323**, but may be disposed at any point disposed between tank charge port **323** and both of low-side charge solenoid **324** and high-side charge solenoid **328**. The arrangement of node **327** only requires direct fluid communication with tank charge port **323**, and thus in practice node **327** may be considered as the head terminus of either seventh channel **322** or eighth channel **326**. In some embodiments, node **327** may effectively be disposed at tank charge port **323**.

It is noted that node **303** serves as both the first tail terminus of the first channel **301** and also the seventh tail terminus of the seventh channel **322**. Thus, seventh channel **322** is in fluid communication with first channel **301**, forming an operable flow path between tank charge port **323** and low-side inlet port **302**. Because of the configuration of low-side charge check valve **325**, refrigerant can only flow completely from the tank charge port **323** toward the low-side inlet port **302**. Similarly, because node **307** serves as the eighth tail terminus of eighth channel **326** and the second tail terminus of second channel **305**, an operable refrigerant flow path is formed between tank charge port **323** and high-side inlet port **306**. Because of the configuration of high-side charge check valve **329**, refrigerant can only flow complete from the tank charge port **323** toward the high-side inlet port **306**. Thus, manifold assembly **300** is configurable to perform a charge operation of the ACS system, providing refrigerant from a storage tank to an air conditioner via low-side inlet port **302** and high-side inlet port **306**. During a charge operation, low-side inlet solenoid **312** and high-side inlet solenoid **316** are closed, while low-side charge solenoid **324** and high-side charge solenoid **328** are opened to permit refrigerant to flow from tank charge port **323** to low-side inlet port **302** and high-side inlet port **306**.

Alternative embodiments may have other configurations for a charge operation without deviating from the teachings herein. As an example, intended for illustration and not limitation, only one of low-side charge solenoid **324** or high-side charge solenoid **328** may be opened to effectively charge the AC using only a single set of channels: seventh channel **322** in combination with first channel **301**, or eighth channel **326** in combination with second channel **305**.

In the depicted embodiment, manifold assembly **300** is additionally configurable to perform a recovery operation of the ACS system, removing refrigerant from an air conditioner and filling it into a storage tank. During a recovery operation, low-side charge solenoid **324** and high-side charge solenoid **328** are closed, while low-side inlet solenoid **312** and high-side inlet solenoid **316** are opened. Refrigerant can thus flow through the low-side inlet port **302** and

high-side inlet port **306** to a compressor via the first channel **301**, second channel **305**, third channel **309**, fourth channel **314** and fifth channel **317**. Refrigerant can then flow from the compressor to a storage tank completing a recovery process via sixth channel **319**. During this recovery operation, the refrigerant flows through at least one of low-side inlet debris filter **311** and high-side inlet debris filter **315**, which removes debris from the refrigerant. Thus, not only are the components of the manifold assembly protected from corrosion and malfunction caused by debris, the compressor will be similarly protected, and no debris will be flushed into the storage tank during the recovery operation.

FIG. 4 depicts a flow diagram another embodiment of an ACS system disclosed herein, having a manifold assembly **400**. In the depicted embodiment, manifold assembly **400** is configured to define a number of passages therein, the passages being operable to provide fluid communication to components of the ACS system, including other passages of manifold assembly **400** or components disposed therein.

The operable fluid communication of the passages disposed therein may be configured using components disposed within the passages. It is recognized that one of ordinary skill in the art would consider the term “passage” to be synonymous with other terms of the art, such as “channel,” “flow path,” “circuit,” “conduit,” or the like. For the purposes of illustration and not limitation, each “passage” as described herein will refer to a sub-portion of the total flow path of manifold assembly **400** comprising a section of flow path disposed between an arbitrary starting point called a “head terminus”, and an arbitrary ending point called a “tail terminus.” A terminus may comprise a particular component disposed within the passage, a particular element or aspect of a particular component within the passage, a port providing fluid communication with the passage, or an arbitrary point along the passage. Termini are not necessarily physical features of a passed, and are referred to herein for the purpose of clarity in describing the embodiment. “Head” termini are referred to as such because they are useful starting points to provide clear description of the embodiment, and the term should not be construed to provide any further meaning. “Tail” termini are referred to as such because they are useful ending points to provide clear description of the embodiment, and the term should not be construed to provide any further meaning. It is recognized that one of ordinary skill in the art would consider the term “terminus” to be synonymous with other terms of the art, such as “locus,” “endpoint,” “extremum,” “focus,” or the like. Within manifold assembly **300** one or more passages may intersect, and a point of intersection may be referred to as a “node.” It is recognized that one of ordinary skill in the art would consider the term “node” to be synonymous with other terms of the art, such as “junction,” “intersection,” “vertex,” or the like. Nodes are not necessarily physical features of one or more channels, and are referred to herein as such for the purpose of clarity in describing the embodiment. Nodes may or may not serve as a head terminus or tail terminus of one or more passages.

In the depicted embodiment, some channels and components thereof may be described using ordinal signifiers (“a first passage”, “a second passage”, etc.). These ordinal signifiers are only referred to as such for the purpose of clarity in describing the embodiment and should not be construed to provide any further meaning. One of ordinary skill in the art will recognize that some alternative embodiments may comprise similar but not identical passages. For the purposes of clarity with respect to these alternative embodiments, the passages will be referred to using the

same ordinal signifiers, even if use of those labels is not technically correct from a semantic view (e.g., an alternative embodiment may comprise a “first passage” and a “third passage” but not a “second passage”). With respect to the disclosure herein, ordinal signifiers may be considered as an arbitrary labeling mechanism.

Manifold assembly **400** defines a first passage **401**, being disposed between a low-side inlet port **402** providing a first head terminus and a node **403**, providing a first tail terminus. Low-side inlet port **402** is configured to be in fluid communication with a corresponding low-side port of an air conditioner (not shown). First passage **401** is further characterized by fluid communication with a low-side inlet pressure transducer **404**, configured to measure the pressure of first passage **401** and provide the measurements to a user or another component of the ACS system. In some embodiments, low-side pressure transducer **404** may instead be embodied as an analog pressure gauge. In the depicted embodiment, low-side inlet pressure transducer **404** is disposed outside of the periphery of manifold assembly **400**, but other embodiments may have other configurations without deviating from the teachings herein.

Manifold assembly **400** further defines a second passage **405**, being disposed between a high-side inlet port **406** serving as a second head terminus and a node **407** serving as a second tail terminus. High-side inlet port **406** is configured to be in fluid communication with a corresponding high-side port of an air conditioner (not shown). Second passage **405** is further characterized by fluid communication with a high-side pressure transducer **408**, configured to measure the pressure of second passage **405** and provide the measurements to a user or another component of the ACS system. In some embodiments, high-side pressure transducer **408** may instead be embodied as an analog pressure gauge. In the depicted embodiment, low-side inlet pressure transducer **404** is disposed outside the periphery of manifold assembly **400**, but other embodiments may have other configurations without deviating from the teachings herein.

Node **403** additionally serves as a third head terminus for a third passage **409**. Third passage **409** is additionally defined by a third tail terminus provided by a node **410**. Third passage **409** is characterized by a low-side inlet debris filter **411** and a low-side inlet solenoid **412**. In the depicted embodiment, low-side inlet debris filter **411** is disposed nearer to third head terminus **403** than low-side inlet debris solenoid **412**, but other embodiments may have alternative configurations without deviating from the teachings herein. Advantageously in the depicted embodiment, low-side inlet debris filter **411** is disposed such that it may protect low-side inlet solenoid **412** from corrosion or malfunction caused by debris within the refrigerant.

Third passage **409** is further characterized by fluid connection with a low-side filter pressure transducer **413**, configured to measure the pressure of the third passage and operable to provide the measurements to a user or another component of the ACS system. The difference between the measurements of low-side filter pressure transducer **413** and low-side inlet pressure transducer **404** may be used to monitor the status of inlet debris filter **411**. If the pressure difference is substantially large, low-side inlet debris filter **411** may be clogged and require servicing. In some embodiments, the ACS system may calculate the difference in pressure measurements automatically and provide an indication that the low-side inlet debris filter **411** requires servicing if the difference is above a predetermined threshold value.

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In the depicted embodiment, the fluid communication point of low-side filter pressure transducer **413** with third channel **409** is disposed between low-side inlet solenoid **412** and third tail terminus **410**, but other embodiments may comprise other arrangements. In practice, low-side filter pressure transducer **413** will be operable when in fluid communication with any point of third channel **409** disposed between low-side inlet debris filter **411** and third tail terminus **410** when low-side inlet solenoid **412** is open. Advantageously, in embodiments where low-side filter pressure transducer **413** is disposed nearer to third head terminus **403** than low-side inlet solenoid **412**, the measurements obtained by low-side filter pressure transducer **413** will be useful even if low-side inlet solenoid **412** is closed. In some embodiments, low-side filter pressure transducer may instead be embodied as an analog pressure gauge. In the depicted embodiment, low-side filter pressure transducer **404** is disposed within the periphery of manifold assembly **400**, but other embodiments may have other configurations without deviating from the teachings herein.

Node **403** additionally serves as a fourth head terminus for a fourth passage **415**, additionally defined by a fourth tail terminus at node **410**. Fourth passage **415** is a parallel passage to third passage **409**, branching away at a node **415**. In the depicted embodiment, node **415** is disposed away from node **403**, but in practice node **415** may be disposed at any point between node **403** and any of low-side inlet debris filter **411** or low-side filter solenoid **412**.

Fourth passage **414** is further characterized by a low-side bypass solenoid **416** disposed between fourth head terminus **403** and fourth tail terminus **410**. Low-side bypass solenoid **416** is configured to operably control the flow of refrigerant between fourth head terminus **403** and fourth tail terminus **410**. In the depicted embodiment, low-side bypass solenoid **416** is normally in a closed state. During service operations of the ACS system, it is desirable that the operation be completed in a timely fashion. If low-side inlet debris filter **411** is clogged with debris, flow velocity through the third passage **409** may be unacceptably slow to complete a service operation in a desired time. To accommodate for unacceptable flow velocity caused by a clogged debris filter, low-side bypass solenoid **416** may be placed into an open state to allow an alternative route past the clogged debris filter. In some embodiments, low-side inlet solenoid **412** may additionally be closed when low-side bypass solenoid **416** is open to optimize flow velocity. In some embodiments, fourth passage **414** may include a debris filter disposed therein. In such embodiments, the debris filter disposed within fourth passage **414** may continue to provide protection of the ACS system components from debris when low-side debris filter **411** is clogged and bypassed by use of the fourth passage **414**. In some such embodiments, the passages may be configured such that the debris filter disposed within an unused passage may be removed and serviced during operation of the ACS system. In some embodiments, additional redundant passages may be utilized to optimize flow velocity or provide additional auxiliary flow paths.

Node **407** additionally provides a head terminus for a fifth passage **417**, also defined by a tail terminus at a node **418**. Fifth passage **417** is characterized by a high-side inlet debris filter **419** and a high-side inlet solenoid **420** disposed therein. In the depicted embodiment, high-side inlet debris filter **419** is disposed nearer to fifth head terminus **407** than low-side inlet debris solenoid **420**, but other embodiments may have alternative configurations without deviating from the teachings herein. Advantageously in the depicted embodiment,

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high-side inlet debris filter **419** is disposed such that it may protect high-side inlet solenoid **420** from corrosion or malfunction caused by debris within the refrigerant.

In the depicted embodiment, fifth tail terminus **418** is in fluid communication with node **410**, and thus low-side filter pressure transducer **413** may be used to measure the pressure of fifth passage **417**, particularly when high-side inlet solenoid **420** is an open state. Thus, the status of high-side inlet debris filter **419** can be monitored based upon the difference in measurements of the low-side filter pressure transducer **413** and the high-side inlet pressure transducer **408**. If the difference between the measurements is sufficiently large, this may indicate a need to service high-side inlet debris filter **419**. In some embodiments, instead of relying upon direct fluid communication between the fifth tail terminus and node **410**, an additional pressure transducer may instead be disposed within the fifth passage **417**. Advantageously, an additional pressure transducer disposed between high-side inlet debris filter **419** and high-side inlet solenoid **420** results in a measurement of the pressure in the fifth passage **417** that does not depend on the arrangement or state of high-side inlet solenoid **420** to useful in determining the condition of high-side inlet debris filter **419**.

Node **407** additionally serves as a sixth head terminus for a sixth passage **421**, additionally defined by a sixth tail terminus at node **418**. Sixth passage **421** is a parallel passage to fifth passage **417**, branching away at a node **422**. In the depicted embodiment, node **422** is disposed away from node **407**, but in practice node **422** may be disposed at any point between node **407** and any of high-side inlet debris filter **419** or high-side filter solenoid **420**. In the depicted embodiment, node **418** is disposed away from and in direct fluid communication with node **410**, but in some embodiments they may comprise a single node.

Sixth passage **421** is further characterized by a high-side bypass solenoid **423** disposed between sixth head terminus **403** and sixth tail terminus **410**. High-side bypass solenoid **423** is configured to operably control the flow of refrigerant between sixth head terminus **403** and sixth tail terminus **410**. In the depicted embodiment, high-side bypass solenoid **423** is normally in a closed state. During service operations of the ACS system, it is desirable that the operation be completed in a timely fashion. If high-side inlet debris filter **419** is clogged with debris, flow velocity through the fifth passage **417** may be unacceptably slow to complete a service operation in a desired time. To accommodate for unacceptable flow velocity caused by a clogged debris filter, high-side bypass solenoid **423** may be placed into an open state to allow an alternative route past the clogged debris filter. In some embodiments, high-side inlet solenoid **420** may additionally be closed when high-side bypass solenoid **423** is open to optimize flow velocity. In some embodiments, sixth passage **421** may include a debris filter disposed therein. In such embodiments, the debris filter disposed within sixth passage **421** may continue to provide protection of the ACS system components from debris when high-side debris filter **419** is clogged and bypassed by use of the sixth passage **421**. In some such embodiments, the passages may be configured such that the debris filter disposed within an unused passage may be removed and serviced during operation of the ACS system. In some embodiments, additional redundant passages may be utilized to optimize flow velocity or provide additional auxiliary flow paths.

In some embodiments, third passage **409**, fourth passage **414**, fifth passage **417** and sixth passage **421** may be configured to work in tandem during a service operation of the ACS system. For example, during a recovery operation,

low-side inlet solenoid **412** and high-side inlet solenoid **420** can each be placed into an open state to permit refrigerant to flow from low-side inlet port **402** and low-side inlet port **406** to the rest of the components of ACS system. If one of low-side inlet debris filter **411** or high-side inlet debris filter **419** should become clogged, refrigerant may still flow at an acceptable velocity through the other passage, and thus low-side bypass solenoid **416** and high-side bypass solenoid **423** may remain closed so that refrigerant is still filtered of debris. If it is determined that the pressure difference on either side of the debris filters is too great, then the low-side bypass solenoid **416** and high-side bypass solenoid **421** may be opened to expedite the recovery operation. Alternatively, in some embodiments only one of third passage **409**, fourth passage **414**, fifth passage **417**, and sixth passage **421** may be utilized at a time by opening only one of low-side inlet solenoid **412**, low-side bypass solenoid **416**, high-side inlet solenoid **420**, or high-side bypass solenoid **421** at a time, with priority given to the inlet solenoids before the bypass solenoids. Other alternative embodiments having other configurations will be apparent to one of ordinary skill in the art without deviating from the teachings herein.

Manifold assembly **400** additionally defines a seventh passage **424**, having a seventh head terminus at a node **425** and a seventh tail terminus defined by an accumulator inlet port **426** of an accumulator **427**. Seventh head terminus **425** is in fluid communication with node **410**, providing direct fluid communication with the third passage **409**, fourth passage **414**, fifth passage **417**, and sixth passage **421**. In the depicted embodiment, node **425** is disposed away from node **410**, but in some embodiments they may comprise a single node. In the depicted embodiment, node **425** is disposed away from node **418**, but in some embodiments they may comprise a single node.

Disposed within seventh passage **424** is a recover solenoid **428** and a recover check valve **429**. In the depicted embodiment, recover solenoid **428** is disposed nearer to seventh head terminus **425**, but other embodiments may have other arrangements. Recover solenoid **428** is configured to permit flow refrigerant from one or more of the third passage **409**, fourth passage **414**, fifth passage **417**, and sixth passage **421** into accumulator **427**, such as during a refrigerant recovery operation of the ACS system. Recover check valve **429** is configured to permit flow of refrigerant from seventh head terminus **425** into accumulator **427** via accumulator inlet port **426**, but also to prevent backflow of refrigerant toward seventh head terminus **425** from seventh tail terminus **426**.

Inside accumulator **427**, refrigerant is stored in a mixture of liquid and gaseous form before advancing to an eighth passage **430**. Accumulator **427** is configured such that only gaseous refrigerant may leave accumulator **427** via an accumulator outlet port **431**, which also serves as an eighth head terminus for eighth passage **430**. Eighth passage **430** is further defined with an eighth tail terminus at a compressor inlet port **432**, providing fluid communication with an inlet of a compressor **433**. Compressor **433** is configured to increase the pressure of gaseous refrigerant, making it more suitable for storage in a storage tank. In the depicted embodiment, compressor **433** is disposed outside of the periphery of the manifold assembly **400**, but other embodiments may have other configurations without deviating from the teachings herein.

Compressor **433** is configured to operate upon refrigerant in gaseous form, and is susceptible to malfunction or damage if exposed to liquid, contaminants, or debris. For this reason, a filter/drier **434** is disposed between eighth head

terminus **431** and eighth tail terminus **432**. Filter/drier **434** is configured to filter particulates and prevent liquids from entering compressor **433**. In the disclosed embodiment, filter/drier **434** is disposed within manifold assembly **400**, but other embodiments may have alternative configurations without deviating from the teachings herein.

Manifold assembly **400** further defines a ninth passage **435** having a ninth head terminus at a compressor return port **436**. Ninth passage **435** is further defined by a ninth tail terminus disposed at a compressor-oil separator inlet **437** of a compressor-oil separator **438**. In the depicted embodiment, ninth passage **435** provides a flow path of gaseous refrigerant to return from compressor **433** to other components of the ACS system via manifold assembly **400**. Because compressor **433** is composed of moving parts, compressor oil may be used to lubricate and protect the compressor **433**, and a quantity of compressor oil may become mixed into the refrigerant as it passes through compressor **433**. Compressor-oil separator **438** is configured to separate the refrigerant from any compressor oil mixed therein, and thus provide only pure refrigerant to other components within the ACS system. In the depicted embodiment, compressor-oil separator **438** is disposed within accumulator **427** forming an accumulator-separator assembly, but other embodiments may have alternative arrangements. In the depicted embodiment, the accumulator-separator assembly is disposed within the periphery of manifold assembly **400**, but other embodiments may have alternative configurations. Because compressor **433** increases the pressure of gaseous refrigerant, the temperature of refrigerant entering compressor-oil separator **438** is increased. Advantageously, because the boiling temperatures of the refrigerant and compressor oil are different, saturated vapor refrigerant further vaporizes, separating the refrigerant from the compressor oil. In an additional advantage, having the compressor-oil separator **438** disposed within accumulator **427** provides an increase in temperature within accumulator **427**, which optimizes conditions for accumulated liquid refrigerant therein to evaporate into gaseous form before passing to compressor **433**, thus helping to prevent liquid refrigerant from entering compressor **433**.

Gaseous refrigerant vaporized in compressor-oil separator **438** is then passed into a heat-exchange coil **440** disposed within accumulator **427** out of a separator vapor outlet **439**. The heat-exchange coil **440** further optimizes heat dissipation from the vaporized refrigerant within heat-exchange coil **440** to liquid refrigerant accumulated within accumulator **427**. In the depicted embodiment, heat-exchange coil **440** is disposed within accumulator **427**, but other embodiments may have other configurations. Some embodiments may not comprise heat-exchange coil **440** without deviating from the teachings herein.

Manifold assembly **400** further defines a tenth passage **441** that is in fluid communication with heat-exchange coil **440** via a heat-exchange outlet port **442**, which serves as tenth head terminus of tenth passage **441**. A tenth tail terminus of tenth passage **441** is defined by a vapor outlet port **443**, which is configured to be in fluid communication with the inlet of a refrigerant storage tank (not shown). Tenth passage **441** is configured to provide a flow path through manifold assembly **400** to a refrigerant storage tank during, for example, a recovery operation of the ACS system.

Manifold assembly **400** further defines an eleventh passage **444**, disposed between a tank charge port **445** serving as an eleventh head terminus, and node **403**, serving as an eleventh tail terminus. Eleventh passage **444** is further characterized by a low-side charge solenoid **446**, configured

to operably control flow of refrigerant between eleventh head terminus **445** and eleventh tail terminus **403**. Eleventh passage **444** is further characterized by a low-side charge check valve **447**, configured to prevent flow from eleventh tail terminus **403** toward eleventh head terminus **445**. In the depicted embodiment, low-side charge solenoid **446** is disposed nearer to eleventh head terminus **445** than low-side charge check valve **447**, but other embodiments may comprise other arrangements. Because node **403** serves as both the eleventh tail terminus of eleventh passage **444** and the first tail terminus of first passage **401**, the two passages are in fluid communication. Thus, manifold assembly **400** is operable to provide a flow path of refrigerant from an external storage tank to the low-side port of the AC (not shown), such as during a charge operation of the ACS to charge the AC with refrigerant. During a charge operation of the ACS, low-side charge solenoid **446** may be in an open state, while low-side inlet solenoid **412** and low-side bypass solenoid **416** should each be in a closed state. Similar configurations will be recognized by one of ordinary skill in the art with respect to other functions of the ACS system, such as a recharge operation.

Tank charge port **445** additionally serves as a twelfth head terminus to a twelfth passage **448**, with node **407** serving as its twelfth tail terminus. Twelfth passage **449** branches from eleventh passage **444** at a node **449**, in direct fluid communication with twelfth head terminus **445**. In the depicted embodiment, node **449** is disposed away from eleventh head terminus **445**, but in other embodiments node **449** may be disposed at any point between eleventh head terminus **445** and any of low-side charge solenoid **446** or low-side charge check valve **447**, including at tank charge port **445**.

Twelfth passage **448** is further characterized by a high-side charge solenoid **450**, configured to operably control flow of refrigerant between twelfth head terminus **445** and twelfth tail terminus **407**. Twelfth passage **448** is further characterized by a high-side charge check valve **451**, configured to prevent flow from twelfth tail terminus **407** toward twelfth head terminus **445**. In the depicted embodiment, high-side charge solenoid **450** is disposed nearer to twelfth head terminus **445** than high-side charge check valve **451**, but other embodiments may comprise other arrangements. Because node **407** serves as both the twelfth tail terminus of twelfth passage **448** and the second tail terminus of second passage **405**, the two passages are in fluid communication. Thus, manifold assembly **400** is operable to provide a flow path of refrigerant from an external storage tank to the high-side port of the AC (not shown), such as during a charge operation of the ACS to charge the AC with refrigerant. During a charge operation of the ACS, high-side charge solenoid **450** may be in an open state, while high-side inlet solenoid **420** and high-side bypass solenoid **423** should each be in a closed state. Similar configurations will be recognized by one of ordinary skill in the art with respect to other functions of the ACS system, such as a recharge operation.

In one embodiment, a charge operation of the ACS system will utilize the flow path formed by eleventh passage **444** and first passage **401** and also the flow path formed by twelfth passage **448** and second passage **405**. During this exemplary charge operation, low-side charge solenoid **446** and high-side charge solenoid **450** are placed in an open state, while all of low-side inlet solenoid **412**, low-side bypass solenoid **416**, high-side inlet solenoid **420**, and high-side bypass solenoid **423** are placed in a closed state. Thus, manifold assembly **400** is operably configured to permit refrigerant to flow from a storage tank, though tank

charge port **445** to both the low-side and high-side ports of an AC via low-side inlet port **402** and high-side inlet port **406** respectively.

Additional features of manifold assembly **400** are operable to provide additional functions of the ACS system. For example, in the depicted embodiment, manifold assembly **400** further comprises a thirteenth passage **452**, having a thirteenth head terminus defined by a tank-fill port **453** configured to be in fluid communication with an external source of refrigerant. The thirteenth passage **452** is further defined by an accumulator tank-fill port **454** acting as a thirteenth tail terminus. Thirteenth passage **454** is further characterized by a tank-fill solenoid **455** configured to operably control flow from thirteenth head terminus **453** to thirteenth tail terminus **454**. Thirteenth passage **452** is further characterized by a tank-fill check valve **456** configured to permit flow from thirteenth head terminus **453** to thirteenth tail terminus **454**.

Thirteenth passage **452** is configured to provide a rapid-fill function of a storage tank in fluid communication with vapor outlet port **443**. An external refrigerant source (not shown) is connected to tank-fill port **453**, providing operable fluid communication between the external refrigerant source and thirteenth passage **452**. In this configuration, tank-fill solenoid **452** is placed into an open state, creating a flow path between the external refrigerant source and accumulator **427**. Compressor **433** can then be engaged to move refrigerant from accumulator **427** into a storage tank (not shown) connected to vapor outlet port **443**, as previously described. In some embodiments, external refrigerant source may be connected to tank-fill port **453** using one or more hoses (not shown). In the depicted embodiment, tank-fill port **453** may be in fluid communication with a filter screen **457**, configured to filter refrigerant from the external refrigerant source of debris. In the depicted embodiment, filter screen **457** is disposed outside the periphery of manifold assembly **400**, though other embodiments may have other arrangements without deviating from the teachings herein. In some embodiments, filter screen **457** may be disposed within the hoses connecting the external refrigerant source to tank-fill port **453**. In some embodiments, filter screen **457** is disposed between tank-fill port **453** and the hoses connecting the external refrigerant source thereto. Some embodiments may not include filter screen **457** without deviating from the teachings herein.

Manifold assembly **400** further defines a fourteenth passage **458**, disposed between a node **459** serving as a fourteenth head terminus, and a node **460** serving as a fourteenth tail terminus. Node **459** is in direct fluid communication with node **449**, thus providing fluid communication between tank charge port **445** and fourteenth passage **548**. In the depicted embodiment, node **459** is disposed away from node **449**, but in some embodiments they may comprise a single node. Node **460** is in direct fluid communication with the accumulator tank-fill port **454** via thirteenth passage **452**. Disposed between fourteenth head terminus **459** and fourteenth tail terminus **460** is a recycle solenoid **461**, configured to control operable fluid communication between the fourteenth head terminus **459** and the fourteenth tail terminus **460**.

In the depicted embodiment, during a tank-fill operation as disclosed above, recover solenoid **461** is configured in a closed state. Other configurations of the fourteenth passage may be utilized for other operations of the ACS system. For example, during a recycle operation, refrigerant in the AC is first recovered, and then the ACS system is configured to replace the AC refrigerant with fresh refrigerant from the

external refrigerant source. For this stage of the process, recycle solenoid **461**, low-side charge solenoid **446** and high-side solenoid **450** are configured in an open state. Then when the external refrigerant source is connected to tank-fill port **453** and tank-fill solenoid **455** is configured into an open state, the pressure differential between the empty AC compared to the external refrigerant source will create flow of refrigerant through the thirteenth passage **452**, and then through fourteenth passage **458** into eleventh passage **444** and twelfth passage **448**. From eleventh passage **444**, refrigerant can flow into first passage **401** and out low-side inlet port **402** into the low-side connection of the AC. From twelfth passage **448**, refrigerant can flow into first passage **405** and out high-side inlet port **406** into the high-side connection of the AC. In some embodiments, this transfer from the external refrigerant source and the AC may be assisted by an AC compressor component of the air conditioner.

Manifold assembly **400**, as depicted, additionally defines a fifteenth passage **462**, a sixteenth passage **463** and a seventeenth passage **464**, each of which provides functions related to the operation of a vacuum pump **465** of the ACS system. Fifteenth passage **462** is defined by a fifteenth head terminus at a node **466** and a fifteenth tail terminus at a vacuum inlet port **467**, configured to be in fluid communication with an inlet of vacuum pump **465**. Node **466** is in direct fluid communication with third tail terminus **410**, fourth tail terminus **418**, and seventh head terminus **425**. In the depicted embodiment, node **466** is disposed away from all of third tail terminus **410**, fourth tail terminus **418**, and seventh head terminus **425**, but other embodiments may have other configurations, including a single node to comprise any combination of node **466**, third tail terminus **410**, fourth tail terminus **418**, and seventh head terminus **425**. Disposed between fifteenth head terminus **466** and fifteenth tail terminus **467** is a vacuum solenoid **468**, configured to control the operable fluid communication between fifteenth head terminus **466** and fifteenth tail terminus **467**. Vacuum pump **465** is operable to create a pressure differential to draw refrigerant from passages in fluid communication with fifteenth passage **462** toward vacuum pump **465**, wherein the refrigerant is condensed. Vacuum pump **465** is configured to flush the condensed refrigerant into sixteenth passage **463**. Sixteenth passage **463** is defined by a sixteenth head terminus at a vacuum pump return port **469** and a sixteenth tail terminus **470** at a deep-recover accumulator inlet **470** of accumulator **427**. Disposed between sixteenth head terminus **469** and sixteenth tail terminus **470** is a deep-recover solenoid **471**, configured to control the operable flow between sixteenth head terminus **469** and sixteenth tail terminus.

The ACS system is operable to perform a vacuum-pull operation which removes errant fluids from within manifold assembly **400** flow paths, or from the flow paths of a connected air conditioner. After a vacuum-pull operation, the ACS system or the AC will left in a near-vacuum state. An exemplary such errant fluid would be air, which is non-condensable and impedes the operation of an air conditioner, and multiple components of the ACS system such as compressor **433**. Manifold assembly further defines a seventeenth passage **464** having a seventeenth head terminus at a node **472**, and a seventeenth tail terminus at a vacuum pump exhaust port **473**. Node **472** is in direct fluid communication with vacuum pump return port **469**. In the depicted embodiment, node **472** is disposed away from vacuum pump return port **469**, but in some embodiments node **472** may be disposed at any point disposed between vacuum pump return port **469** and deep-recover solenoid **471**. Seventeenth pas-

sage **464** is further characterized by a vacuum exhaust check valve **474**, configured to permit flow between seventeenth head terminus **472** and seventeenth tail terminus **473**.

In an exemplary vacuum-pull operation, an AC first subjected to a recover operation while connected to low-side inlet port **402** and high-side inlet port **406**. The AC is thus devoid of refrigerant, but not yet in a near-vacuum state because a quantity of air remains therein. Manifold assembly **400** is then configured such that vacuum solenoid **468** and at least one of low-side inlet solenoid **412**, low-side bypass solenoid **416**, high-side inlet solenoid **420**, and high-side bypass solenoid **423** are in an open state. Advantageously, in embodiments wherein only at least one of low-side inlet solenoid **412** and high-side inlet solenoid **420** are open, refrigerant from the AC will pass through one of low-side inlet debris filter **411** or high-side inlet debris filter **419**, thus protecting vacuum pump **465** from malfunction caused by debris. The errant air is then pulled into vacuum **465**. Because air is non-condensable, the air will then flow into sixteenth passage **463**. Because deep-recover solenoid **471** is in a closed state, the air will instead flow into seventeenth passage **464** to pass exhaust check valve **464**. Exhaust check valve **464** is normally forced closed by the atmospheric pressure of the environment beyond the periphery of manifold assembly **400**, but as air exists vacuum pump **465**, pressure inside seventeenth passage **464** will increase until exhaust check valve **464** is opened, and the air is vented through exhaust port **473**. The particular near-vacuum state that is capable of being created will depend upon the specification of vacuum pump **465**. In one embodiment, vacuum pump **465** in coordination with compressor **433** is operable to pull the AC to a near-vacuum state having an absolute pressure of less than 1.0 bar, while the compressor **433** is operable to pull an air conditioner to a pressure measuring  $-4$  in-Hg.

As noted previously, compressor **433** may utilize compressor oil to protect and lubricate the moving parts therein, and compressor-oil separator **438** separates refrigerant from compressor-oil that is introduced to the refrigerant as it flows through compressor **433**. An air conditioner may also comprise an AC compressor that requires oil for similar reasons, and thus incoming refrigerant may in fact be a mixture of refrigerant and oil. Manifold assembly **400** further defines an eighteenth passage **475** having components to separate incoming refrigerant from oil of the AC. Nineteenth passage **475** is in fluid communication with accumulator **427** via an oil drain outlet **476**, which additionally acts as a nineteenth head terminus for nineteenth passage **475**. Nineteenth passage **475** is additionally defined by a nineteenth tail terminus at an oil drain port **477**, which is configured to be in fluid communication with an oil drain bottle **478**. In the depicted embodiment, oil drain bottle **478** comprises a bottle, but other embodiments may comprise other forms of receptacles without deviating from the teachings herein. Nineteenth passage **475** is additionally characterized by an oil drain solenoid **479** disposed between nineteenth head terminus **476** and nineteenth tail terminus **477**. Oil drain solenoid **479** is configured to control the operable flow of oil separated from refrigerant in accumulator **427** between oil drain outlet **476** and oil drain port **477**. In the depicted embodiment, oil drain solenoid **479** may be placed into an open state when it is determined that the quantity of oil within accumulator **427** is above a threshold value, indicating an overabundance of oil therein that reduces the efficiency of the ACS system. One method for determining a condition of overabundance is by measuring the pressure within accumulator **427**. In normal operation, the refrigerant within accumulator **427** is

under pressure, causing vaporization. This additionally helps separate the refrigerant from any oil therein, which causes the oil/refrigerant mixture to stratify with the oil at the bottom of the accumulator. In the present embodiment, an accumulator pressure transducer **480** provides a measurement of the pressure within accumulator **427**. Oil drain solenoid **479** may be placed into an open state to drain oil from accumulator. In some embodiments, this process is performed manually by a user monitoring the measurements of accumulator pressure transducer **427**. In some embodiments, this process is performed automatically by the ACS system. Accumulator pressure transducer **480** is depicted herein in fluid communication with a node **481**, disposed within eighth passage **430**. However, other embodiments may have alternative arrangements wherein accumulator pressure transducer is in fluid communication with accumulator **427**. In the depicted embodiment, accumulator pressure transducer **480** is disposed within the periphery of manifold assembly **400**, but other embodiments may have alternative arrangements. In some embodiments, accumulator pressure transducer **480** may instead comprise an analog pressure gauge.

With further regard to oil drain bottle **478**, oil drain bottle **478** may be serviced to remove the excess oil from the ACS. In one embodiment, the entire oil drain bottle **478** may be removed from the ACS system to be emptied of excess oil. In another embodiment, oil drain bottle **478** may comprise a drain outlet to empty oil drain bottle into another receptacle. One of ordinary skill will recognize other embodiments having alternative configurations that do not deviate from the teachings herein. In some embodiments, the oil taken from oil drain bottle **478** may be of sufficient quality to be re-used in an air conditioner. In some embodiments, the oil recovered from accumulator **427** may be of the same type as utilized by compressor **433** or vacuum pump **465**.

In the depicted embodiment, compressor-oil separator **438** is configured to return compressor oil separated therein from refrigerant to compressor **433**. Manifold assembly **400** is configured to define a nineteenth passage **482**, having a nineteenth head terminus comprising an oil return straw **483** disposed within compressor-oil separator **438**. Nineteenth passage **482** further is defined by an oil return port **484**, which is in fluid communication with a compressor-oil inlet of compressor **433**. Nineteenth passage **482** is further characterized by an oil return solenoid **485** disposed between nineteenth head terminus **483** and nineteenth tail terminus **484**. Oil return solenoid **485** is configured to control the operable fluid communication between the compressor-oil separator **438** and oil return port **484**. Oil return solenoid may be opened upon determination that it is appropriate to return oil in compressor-oil separator **438** to compressor **433**. In some embodiments, this determination may be made based upon pressure measurements within compressor-oil separator **438**, in a manner similar to that described above with respect to accumulator **427**. In some embodiments, oil drain solenoid **485** may be placed into an open condition at regular intervals during active operation of compressor **433**. The particular load cycle of the oil drain solenoid **485** may be determined based upon the specification of compressor **433**, the conditions within compressor-oil separator **438**, the particular operation being performed by the ACS system, or any other condition that would be known to one of ordinary skill in the art. In one exemplary embodiment, given by way of example and not limitation, oil return solenoid **485** is initially open during a recover operation for three seconds, and then opened again for an additional three seconds out for every ten-minute interval that compressor **433** is active.

Manifold assembly **400** may define other additional passages that enable additional utility to the ACS system. In the depicted embodiment, a twentieth passage **486** is defined, having a twentieth head terminus at node **481** and a twentieth tail terminus at a service port **487**. Service port **487** provides direct fluid communication with accumulator pressure transducer **481**, and thus can be used to check the calibration of accumulator pressure transducer **481** against the readings of an external pressure measurement tool. In the depicted embodiment, accumulator transducer **480** is placed into direct fluid communication with twentieth head terminus **481**, but other embodiments may have other configurations wherein service port **487** is configured with direct fluid communication to accumulator pressure transducer **481** without deviating from the teachings herein. In some embodiments, service port **487** may be closed using a plug, cap, or other sealing device known to one of ordinary skill in the art (not shown). In some embodiments, service port **487** may be configured as a normally-closed connection valve that may only open when coupled to an appropriate connector or fitting. Other equivalent embodiments of service port **487** will be recognized by one of ordinary skill in the art without deviating from the teachings herein.

Low-side inlet pressure transducer **404** is similarly disposed such that its calibration may be compared to an external pressure measurement tool in fluid communication with low-side inlet port **402**. High-side inlet pressure transducers **408** is similarly disposed such that its calibration may be compared to an external pressure measurement tool in fluid communication with high-side inlet port **408**. Low-side filter transducer **413** is similarly disposed such that its calibration may be compared to an external pressure measurement tool in fluid communication with either low-side inlet port **402** or high-side inlet port **408**, provided that an appropriate combination of low-side inlet solenoid **412**, low-side bypass solenoid **416**, high-side inlet solenoid **420**, and high-side bypass solenoid **423** are placed into an open state.

Also depicted in FIG. 4 is a high pressure cut-off switch **488**, disposed within ninth passage **435**. High pressure cut-off switch is configured to measure the pressure within the ninth passage **435** and to terminate operation of the ACS system in the event that the pressure therein becomes higher than a threshold value. The threshold value may be chosen such that it represents pressure levels capable of causing failure of components within the ACS system or damage to components of the ACS system, the AC, or interconnections thereof. In the depicted embodiment, high-pressure cut-off switch is configured to disconnect electrical power from the ACS system, stopping operation of vacuum pump **465** and compressor **433**. In some embodiments, some of the solenoids disposed within manifold assembly **400** may be normally-closed solenoids, and thus loss of electrical power will close such solenoids. In the depicted embodiment, high-pressure cutoff switch **488** is disposed within ninth passage **435**, but other embodiments may comprise alternative configurations without deviating from the teachings herein. Advantageously, in the depicted embodiment, ninth passage **435** is expected to be subjected to the highest pressure levels within manifold assembly **400**, being in fluid communication with the output of compressor **433** providing condensed gaseous refrigerant and also with compressor-oil separator **438**, which is filled with the condensed gaseous refrigerant and also subjected to additional heat from heat-exchange coil **440** and the pressure within accumulator **427**. In some embodiments, manifold assembly **400** may comprise additional cutoff switches. In the depicted

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embodiment, high pressure cutoff switch is entirely disposed within the periphery of manifold assembly 400, but other embodiments may have alternative configurations with high pressure cutoff switch being in fluid communication with the flow path of manifold assembly 400 or one of the components disposed within manifold assembly 400.

FIG. 5 shows an illustration of an embodiment of filter cartridge 208 having an inlet debris filter. The depicted embodiment comprises a cartridge body 500 in the form of a port plug 502, in this case shaped like a bolt-head such that a standard wrench may turn the cartridge body 500, with a fitted insert 504, in this case threaded such that when the cartridge body 500 is turned the fitted insert 504 may thread into an opposing threaded surface of a manifold port. A debris filter 506 fits onto the end of the cartridge body 500 along a horizontal fitting direction 508. When assembled, the filter cartridge 500 may be inserted into a cartridge port of a manifold assembly (see FIG. 2). The manifold assembly may be configured such that the debris filter 502 is placed within the flow path of the manifold assembly via a cross-drilled aperture 510 of the cartridge body 500. FIG. 5 shows one embodiment of a filter cartridge 208, but other embodiments may have different configurations than a cross-drilled aperture to permit flow. In the depicted embodiment, fitted insert 504 comprises a threaded insert, but other embodiments may comprise flanges or another alternative equivalent for coupling cartridge body 500 to a cartridge port.

Debris filter 506 comprises a wire mesh screen affixed to a sealing gasket. Debris filter 506 is configured to be removable from cartridge body 500 when displaced from a cartridge port. The wire mesh screen size is chosen based upon the expected conditions of the refrigerant and the ACS system, but in one exemplary embodiment the screen comprises a 10 micron screen, configured to trap debris having dimensions larger than the mesh of the screen. In the depicted embodiment, the wire mesh screen of debris filter 506 is serviceable such that any debris collected within debris filter 506 can be such that debris filter 506 may be placed back into cartridge body 500 and used again. In one embodiment, servicing of the debris filter 506 to clear collected debris is performed using compressed air to clear the wire mesh screen. In some embodiments, debris filter 506 may not be serviceable. Advantageously, the serviceability of debris filter 506 as described herein may extend the lifetime of debris filter 506 to match that of the ACS system as a whole. In some embodiments, cartridge body 500 may comprise a latching mechanism, couple mechanism, shaped cavity, or other configuration operable to ensure coupling of debris filter 506 to the end of cartridge body 500.

FIG. 6 shows a diagrammatic cross-sectional view of an embodiment of a filter cartridge 208 while coupled to an embodiment of a manifold assembly bloc 600 via cartridge port 206. In the depicted embodiment, the cross-drilled aperture 506 is configured to be in alignment with an inlet aperture 602 defined by the manifold assembly bloc 600. Fitted insert 504 couples with a cavity formed within manifold assembly bloc 600 in such a way to prevent fluid leaks. Cartridge body 500 further comprises an O-ring 604 disposed between port plug 502 and fitted insert 504 configured to seal cartridge port 206 in order to prevent leaks of liquid or gaseous fluids. In the depicted embodiment, fitted insert 504 is threaded to match threads defined by manifold assembly bloc 600, though other embodiments may be configured to accept other configurations of fitted insert 504 without deviating from the teachings herein.

As depicted in FIG. 6, refrigerant flows through inlet aperture 602 and enters the filter cartridge 208 through

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cross-drilled aperture 510. As refrigerant continues to flow therein, it is flushed past debris filter 502 in a direction 606 into a flow path 608 defined by manifold assembly bloc 600. Thus, any debris larger than the screen mesh of debris filter 506 is trapped behind the screw, and the fluid refrigerant continues to flow past the screen.

Fitted insert 504, O-ring 604 and port plug 502 are configured to prevent any leakage of refrigerant during flow while also sufficiently holding cartridge body 500 in place. Thus, fitted insert 504, O-ring 604 and port plug 502 are configured to hold filter cartridge 208 in place with sufficient force such that the pressure of the flow of refrigerant does not displace filter cartridge 208 from cartridge port 206.

In an aspect of the teachings herein, the manifold assembly bloc 600 is configured such that refrigerant is only expected to flow in direction 606. Because the refrigerant does not backflow against direction 606, the collected debris remains trapped behind debris filter 506 during normal operation of the ACS system. For example, referring back to FIG. 4, low-side inlet debris filter 411 is disposed such that during a recover operation refrigerant will flow from third head terminus 403 toward third tail terminus 410. However, node 410 is in direct fluid communication with seventh passage 424, comprising recover check valve 429, configured to prevent flow of refrigerant from seventh tail terminus 426 toward seventh head terminus 425. Thus, refrigerant will not flow back from third tail terminus 410 toward third head terminus 415, and the collected debris in low-side inlet debris filter 411 will not be flushed out of filter cartridge 208. Other debris filter components of other embodiments of the teachings herein may be similarly advantageously configured. In some embodiments, inlet aperture 602 may comprise additional components to prevent backflow of refrigerant at the filter cartridge 208, such as a check valve or other alternative equivalent known to one of ordinary skill in the art. Because refrigerant does not flush the debris past debris filter 506, and because refrigerant does not flow in the other direction away from filter cartridge 208, debris will remain collected within filter cartridge 208 until such time that it is removed and serviced.

While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the disclosed apparatus and method. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the disclosure as claimed. The features of various implementing embodiments may be combined to form further embodiments of the disclosed concepts.

What is claimed is:

1. A refrigerant recovery, recharging and recycling system comprising:

a number of hoses configured to connect the refrigerant recovery, recharging and recycling system to an air conditioning system, the hoses being operable to permit flow of refrigerant in two directions;

a manifold assembly defining a number of passages in operable fluid communication with the number of hoses, and the manifold assembly configured to permit flow of refrigerant from the air conditioning system to a storage tank, the manifold having a cartridge port disposed within the manifold assembly between an inlet port of the manifold assembly in fluid communication with the hoses and other components disposed within the number of passages of the manifold assembly;

- a compressor in fluid communication with the manifold assembly operable to provide the flow of refrigerant from the air conditioning system to the storage tank; and
  - a filter cartridge connected to the manifold assembly at the cartridge port, the filter cartridge having a filter suitable to collect debris within the refrigerant during a refrigerant cycling process, wherein the filter cartridge further comprises a mating plug that keeps the filter cartridge in place during the refrigerant recovery process, the mating plug further comprising a number of inlet flow apertures in fluid communication with the filter and a number of outlet apertures of the filter cartridge in fluid communication with the manifold assembly.
2. The system of claim 1, wherein the operable fluid communication of the manifold assembly is controlled using solenoids or check valves, and the filter cartridge is disposed between the number of hoses and a first of the solenoids or check valves as refrigerant flows from the air conditioning system.
3. The system of claim 1, the manifold assembly further defining:
- a low-side port operable to provide fluid communication with one of the number of hoses, a high side port operable to provide fluid communication with the one or another of the number of hoses, a compressor inlet port operable to provide fluid communication with an inlet of the compressor, a compressor return port operable to provide fluid communication with an outlet of the compressor, a tank inlet port operable to provide fluid communication with a tank, a charge port operable to provide fluid communication with the tank;
  - a first channel characterized by a first head terminus in fluid communication with the low-side port, and a first tail terminus;
  - a second channel characterized by a second head terminus in fluid communication with the high-side port, and a second tail terminus;
  - a third channel characterized by a third head terminus in fluid communication with the first tail terminus, a low-side inlet debris filter disposed within the filter cartridge and in fluid communication with the third head terminus, a low-side inlet solenoid disposed between the low-side inlet debris filter and a third tail terminus;
  - a fourth channel characterized by a fourth head terminus in fluid communication with the second tail terminus, a high-side inlet debris filter disposed within the filter cartridge and in fluid communication with the fourth

- head terminus, and a high-side inlet solenoid disposed between the high-side inlet debris filter and a fourth tail terminus in fluid communication with the third tail terminus;
  - a fifth channel characterized by a fifth head terminus in fluid communication with the third tail terminus and a fifth tail terminus configured to be in fluid communication with the compressor inlet port;
  - a sixth channel characterized by a sixth head terminus in fluid communication with the compressor return port and a sixth tail terminus in fluid communication with a tank inlet port;
  - a seventh channel characterized by a seventh head terminus in fluid communication with the charge port, a low-side charge solenoid in fluid communication with the seventh head terminus, and low-side charge check valve disposed between the low-side charge solenoid and a seventh tail terminus in fluid communication with the first tail terminus, the low-side charge check valve configured to permit flow from the low-side charge solenoid to the seventh tail terminus; and
  - an eighth channel characterized by an eighth head terminus in fluid communication with the charge port, a high-side charge solenoid in fluid communication with the eighth head terminus, and a high-side charge check valve disposed between the high-side charge solenoid and an eighth tail terminus in fluid communication with the second tail terminus, the high-side charge check valve configured to permit flow from the high-side charge solenoid to the eighth tail terminus.
4. The system of claim 3, the manifold assembly being further characterized by:
- the first channel being in fluid communication with a low-side inlet pressure transducer;
  - the second channel being in fluid communication with a high-side inlet pressure transducer;
  - the third channel being in fluid communication with a low-side filter transducer, the point of fluid communication of the low-side pressure transducer being disposed in the third channel between the low-side inlet debris and the third tail terminus.
5. The system of claim 1, wherein the filter is operable to be removed from the filter cartridge.
6. The system of claim 5, wherein the filter when removed from the filter cartridge is a serviceable filter that may be re-used after servicing.
7. The system of claim 1, wherein the filter is a 10 micron screen such that collected debris larger than 10 micron is prevented from passing the filter.

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